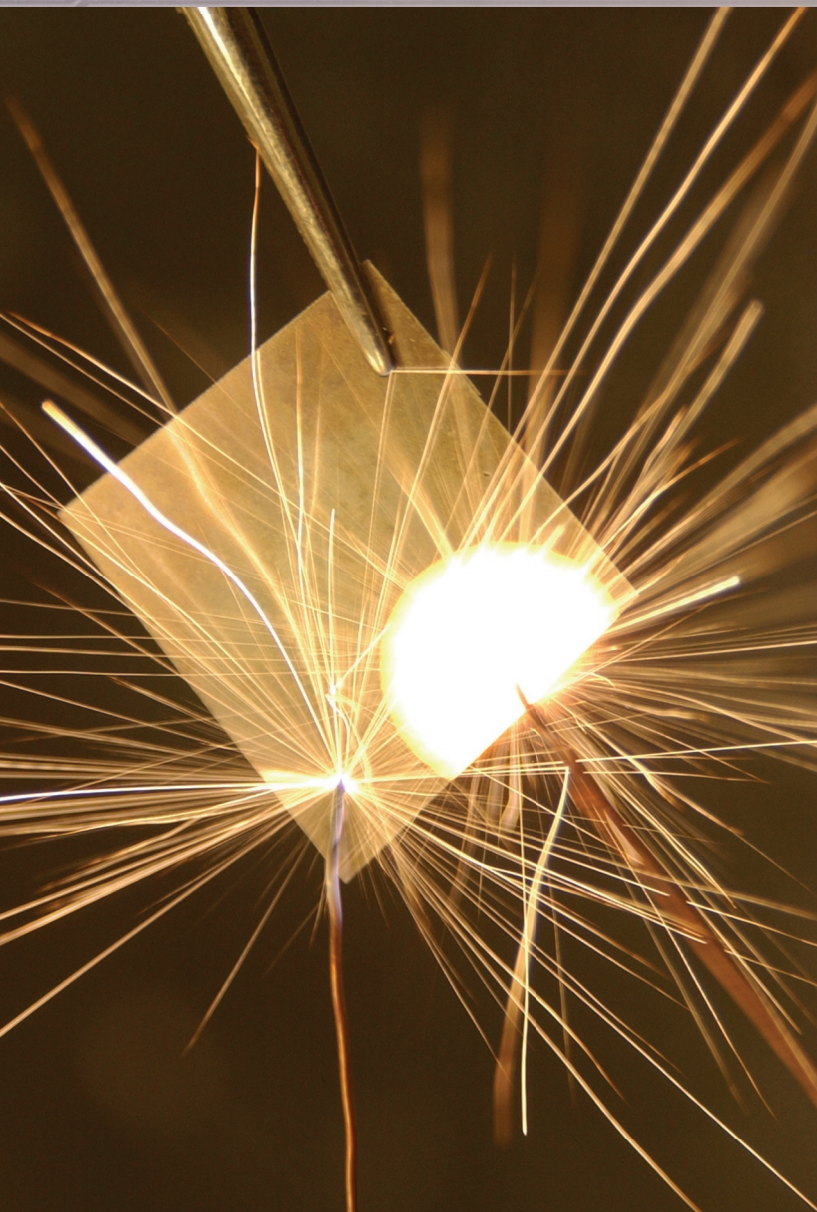


NanoFoil® Solders with Less Heat



When a NanoFoil® is soldered, the reaction propagates outward at about 5 meters per second. In the reaction region (white area), the temperature has jumped to 1,500°C, while the remainder of the foil is still at room temperature. (Image courtesy of Reactive NanoTechnologies.)

H EAT is becoming one of the most critical issues in computer and semiconductor design,” says Intel Corporation’s Chief Technology Officer, Pat Gelsinger. As microprocessors in computers operate faster, they produce more heat. However, the difficulty of conducting this increased heat out of a chip is limiting both chip performance and reliability. The most effective way to get heat into the heat sink would be to attach the chip package with a conductive metallic bond such as a solder. But soldering the components in a hot furnace can damage or destroy the chip. Epoxies do not damage the chip, but they tend to degrade over time, and their bond is weaker and conducts substantially less heat than a metallic soldered joint.

Enter NanoFoil®, a revolutionary product that creates a strong, thermally conductive bond between a heat sink and a chip, with no damage to the chip. NanoFoil delivers just enough heat to melt the solder but not enough to damage a chip. When one end of the foil is pulsed with energy, NanoFoil’s thousands of nanolayers of nickel and aluminum begin to chemically react and release heat into the surrounding solder material. This reaction front self-propagates across the foil, causing the temperature of the reacted area to leap to more than 1,500°C while the remainder of the foil is still at room temperature. This process energizes the formation of what is termed a NanoBond™. The NanoBond process works in air, in a vacuum, or in argon gas, and it is completed in a second or less.

NanoFoil grew out of technology used to fabricate multilayer x-ray and extreme-ultraviolet optics at Lawrence Livermore. Materials scientist Troy Barbee, Jr., began much of the early work on reactive foils as part of a broad multilayer, nanolaminate project initially funded by Livermore’s Laboratory Directed Research and Development Program. Postdoctoral researcher Timothy Weihs and Barbee worked on reactive nanolaminate materials as part of a Cooperative Research and Development Agreement in the mid-1990s. In 1995, Weihs joined the faculty at Johns Hopkins University where he teamed with Omar Knio (then a professor at Johns Hopkins) and others to further develop reactive foils for use as localized heat sources for soldering and brazing. In 2001, Weihs and Knio founded Reactive NanoTechnologies (RNT) in Hunt Valley, Maryland, to commercialize NanoFoil.

Manufactured and sold exclusively by RNT, NanoFoil can be used to bond metals, ceramics, semiconductors, and polymers. It can also bond dramatically dissimilar kinds of materials without causing the materials to crack. NanoFoil is a new class of material and is one of the most mature nanotechnologies available today.

Because of NanoFoil's unique properties, the technology is getting considerable high-profile exposure. It was featured on the cover of the *Strategic Plan for the National Nanotechnology Initiative* published in December 2004 by the Executive Office of the President. More recently, RNT, Lawrence Livermore, and Johns Hopkins University won an R&D 100 Award for NanoFoil.

Benefits Abound

The NanoFoil technology can replace reflow soldering, a common process for mounting components on printed circuit boards that requires multiple, time-consuming runs through a furnace. NanoFoil also eliminates the need for potentially toxic, lead-based solders.

Compared with other joining methods, NanoFoil is a major cost saver. It can replace expensive capital equipment such as the furnaces and torches used in conventional soldering or brazing operations. Similarly, newer bonding methods such as laser and resistive welding, developed to get around the limitations of traditional soldering and brazing, have significant capital costs up front.

NanoFoil can be manufactured in a range of sizes, allowing both large and small components to be bonded, and it can be customized for specific uses. The properties of the chemical reaction, such as velocity and temperature, can be controlled by varying the thickness of individual nanolayers or the average chemistry or total thickness of the foil. The velocity of the reaction increases significantly as the thickness of each aluminum-nickel bilayer decreases. In thinner layers, the atoms intermix more easily, and the reactions propagate faster. Each bilayer typically is about 50 nanometers thick with approximately 25 atoms across its thickness. RNT engineers can adjust the thickness to within a few nanometers to obtain the NanoFoil properties needed for a particular job.

From Chips to Missiles

RNT has identified many potential uses for NanoFoil besides attaching computer chips to heat sinks. It offers a replacement for epoxies and solder in manufacturing circuit boards, saving money and time and eliminating the need for lead-based solders. RNT developed the NanoBond process for mounting radio-frequency connectors on printed circuit boards in conjunction with Agilent Technologies of Palo Alto, California.

As the first technology to create strong, large-area metallic joints between ceramic and metal, NanoFoil may be used in the near future to attach ceramic armor tiles to U.S. Army tanks and trucks. Epoxies are used now, although their bonds are weak and typically fail with

a single ballistic hit. Worse yet, when a single tile is hit, the shock wave causes neighboring armor tiles to pop off. BAE Systems, an international defense and aerospace contractor, has an exclusive development agreement with RNT for the use of NanoFoil to mount armor on military vehicles.

NanoFoil can also be used to mount magnetron sputtering targets; to hermetically seal photocells, capacitors, sensors, and other devices; and to ignite solid propellants. Other possible applications are as infrared decoys to defeat heat-seeking missiles and in intercepting missiles to provide structural integrity and to release energy on impact.

Joining and bonding materials are important to almost every commercial and defense market. The NanoBond process is fast, strong, inexpensive, and environmentally friendly—and it promises significant benefits to U.S. manufacturing.

—Katie Walter

Key Words: computer industry, NanoBond™ process, NanoFoil®, nanotechnology, R&D 100 Award.

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